

CLAIMS

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1. A multi-stage optical amplifier, comprising:
an optical fiber including a first length of amplifier fiber and a
second length of amplifier fiber, the optical fiber configured to be coupled
to a signal source that produces at least a signal wavelength λ_s and a pump
source that produces a pump wavelength λ_p , wherein pump wavelength λ_p
is less than signal wavelength λ_s ;
a signal input port coupled to the optical fiber;
a signal output port coupled to the optical fiber;
a pump input port coupled to the optical fiber;
a first lossy member coupled to the optical fiber and positioned
between the first and second lengths of amplifier fiber, the first lossy
member being lossy in at least one direction; and
a pump shunt coupled to the signal input port and the signal output
port.
2. The multi-stage optical amplifier of claim 1, wherein the
first and lengths of amplifier fiber each have a length greater than or equal
to 200m.
3. The multi-stage optical amplifier of claim 1, wherein pump
radiation of wavelength λ_p is in the range of 1300 nm to 1530 nm
4. The multi-stage optical amplifier of claim 1, wherein signal
radiation of wavelength λ_s is in the range of 1430 to 1530 nm.
5. The multi-stage optical amplifier of claim 1, wherein the
first lossy member is an optical isolator.
6. The multi-stage optical amplifier of claim 1, wherein the
first lossy member is an add/drop multiplexer.
7. The multi-stage optical amplifier of claim 1, wherein the
first lossy member is a gain equalization member.

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- 2 8. The multi-stage optical amplifier of claim 1, wherein the
1 first lossy member is a dispersion compensation element.
- 1 9. The multi-stage optical amplifier of claim 1, wherein the
2 first length of amplifier fiber is a Raman amplifier
- 1 10. The multi-stage optical amplifier of claim 1, wherein the
2 second length of amplifier fiber is a Raman amplifier.
- 1 11. The multi-stage optical amplifier of claim 1, wherein at
2 least one of the first and second Raman fiber amplifiers is a dispersion
3 compensating fiber.
- 1 12. The multi-stage optical amplifier of claim 11, wherein the
2 first and Raman fiber amplifiers are each dispersion compensating fibers.
- 1 13. The multi-stage optical amplifier of claim 1, wherein the
2 first length of amplifier fiber has lower noise than the second length of
3 amplifier fiber.
- 1 14. The multi-stage optical amplifier of claim 1, wherein the
2 second length of amplifier fiber has a higher gain than the first length of
3 amplifier fiber.
- 1 15. The multi-stage optical amplifier of claim 1, further
2 comprising:
3 at least one WDM coupler to couple a pump path from the signal
4 input port to the signal output port.
- 1 16. The multi-stage optical amplifier of claim 1, wherein the
2 first length of amplifier fiber has an optical noise figure of less than 8 dB.
- 1 17. The multi-stage optical amplifier of claim 1, wherein the
2 second length of amplifier fiber has a gain level of at least 5 dB.

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- 1 18. The multi-stage optical amplifier of claim 1, further
2 comprising:
3 a pump source coupled to the pump input port.
- 4 19. The multi-stage optical amplifier of claim 1, further
5 comprising:
6 at least one laser diode pump source coupled to the pump input
7 port.
- 1 20. The multi-stage optical amplifier of claim 1, further
2 comprising:
3 a second lossy member coupled to the pump shunt.
- 4 21. The multi-stage optical amplifier of claim 1, wherein the
5 pump shunt includes an optical fiber.
- 1 22. A broadband booster amplifier, comprising:
2 a plurality of transmitters transmitting a plurality of wavelengths;
3 a combiner coupled to the plurality of transmitters;
4 an optical fiber coupled to the combiner, the optical fiber including
5 a first length of amplifier fiber and a second length of amplifier fiber, the
6 optical fiber configured to be coupled to a signal source and a pump
7 source;
8 a signal input port coupled to the optical fiber;
9 a signal output port coupled to the optical fiber;
10 a pump input port coupled to the optical fiber;
11 a first lossy member coupled to the optical fiber and positioned
12 between the first and second lengths of amplifier fiber, the first lossy
13 member being lossy in at least one direction; and
14 a pump shunt coupled to the signal input port and the signal output
15 port.

1 23. A broadband pre-amplifier, comprising:
 2 an optical fiber including a first length of amplifier fiber and a
 3 second length of amplifier fiber, the optical fiber configured to be coupled
 4 to a signal source and a pump source;
 5 a signal input port coupled to the optical fiber;
 6 a signal output port coupled to the optical fiber;
 7 a pump input port coupled to the optical fiber;
 8 a first lossy member coupled to the optical fiber and positioned
 9 between the first and second lengths of amplifier fiber, the first lossy
 10 member being lossy in at least one direction;
 11 a pump shunt coupled to the signal input port and the signal output
 12 port;
 13 a splitter coupled to the signal output port; and
 14 a plurality of receivers coupled to the splitter.

1 24. A broadband communication system, comprising:
 2 a transmitter;
 3 an optical fiber including a first length of amplifier fiber and a
 4 second length of amplifier fiber, the optical fiber configured to be coupled
 5 to a signal source and a pump source;
 6 a signal input port coupled to the optical fiber;
 7 a signal output port coupled to the optical fiber;
 8 a pump input port coupled to the optical fiber;
 9 a first lossy member coupled to the optical fiber and positioned
 10 between the first and second lengths of amplifier fiber, the first lossy
 11 member being lossy in at least one direction;
 12 a pump shunt coupled to the signal input port and the signal output
 13 port; and
 14 a receiver coupled to the optical fiber.

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25. The system of claim 24, wherein the first and lengths of amplifier fiber each have a length greater than or equal to 200m.
26. The system of claim 24, further comprising:
a pump source producing radiation of wavelength λ_p in the range of 1300 nm to 1530 nm
27. The system of claim 24, further comprising:
a signal source producing radiation of wavelength λ_s in the range of 1430 to 1530 nm.
28. The system of claim 24, wherein the first lossy member is an optical isolator.
29. The system of claim 24, wherein the first lossy member is an add/drop multiplexer.
30. The system of claim 24, wherein the first lossy member is a gain equalization member.
31. The system of claim 24, wherein the first lossy member is a dispersion compensation element.
32. The system of claim 24, wherein the first length of amplifier fiber is a Raman amplifier.
33. The system of claim 24, wherein the second length of amplifier fiber is a Raman amplifier.
34. The system of claim 24, wherein at least one of the first and second Raman fiber amplifiers is a dispersion compensating fiber.
35. The system of claim 34, wherein the first and Raman fiber amplifiers are each dispersion compensating fibers.
36. The system of claim 24, wherein the first length of amplifier fiber has lower noise than the second length of amplifier fiber.
37. The system of claim 24, wherein the second length of amplifier fiber has a higher gain than the first length of amplifier fiber.

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- 1 38. The system of claim 24, further comprising:
2 at least one WDM coupler to couple a pump path from the signal
3 input port to the signal output port.
- 1 39. The system of claim 24, wherein the first length of
2 amplifier fiber has an optical noise figure of less than 8 dB.
- 1 40. The system of claim 24, wherein the second length of
2 amplifier fiber has a gain level of at least 5 dB.
- 1 41. The system of claim 24, further comprising:
2 a laser diode pump source coupled to the pump input port.
- 1 42. The system of claim 24, further comprising:
2 a second lossy member coupled to the pump shunt.
- 1 43. The system of claim 24, wherein the pump shunt includes
2 an optical fiber.
- 1 44. A broadband communication system, comprising:
2 a transmitter;
3 an optical fiber coupled to the transmitter, the optical fiber
4 including a first length of amplifier fiber and a second length of amplifier
5 fiber, the optical fiber configured to be coupled to a signal source and a
6 pump source;
7 a signal input port coupled to the optical fiber;
8 a signal output port coupled to the optical fiber;
9 a pump input port coupled to the optical fiber;
10 a first lossy member coupled to the optical fiber and positioned
11 between the first and second lengths of amplifier fiber, the first lossy
12 member being lossy in at least one direction;
13 a pump shunt coupled to the signal input port and the signal output
14 port;
15 at least one in-line broadband amplifier coupled to the optical fiber;

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16 and

17 a receiver coupled to the in-line broadband amplifier.

1 45. The system of claim 44, wherein the in-line broadband
2 amplifier comprises:

3 an optical fiber including a first length of amplifier fiber and a
4 second length of amplifier fiber, the optical fiber configured to be coupled
5 to a signal source and a pump source;

6 a signal input port coupled to the optical fiber;

7 a signal output port coupled to the optical fiber;

8 a pump input port coupled to the optical fiber;

9 a first lossy member coupled to the optical fiber and positioned
10 between the first and second lengths of amplifier fiber, the first lossy
11 member being lossy in at least one direction; and

12 a pump shunt coupled to the signal input port and the signal output
13 port.

1 46. A broadband communication system, comprising:

2 a transmitter;

3 a broadband booster amplifier;

4 an optical fiber coupled to the broadband booster amplifier, the
5 optical fiber including a first length of amplifier fiber and a second length
6 of amplifier fiber, the optical fiber configured to be coupled to a signal
7 source and a pump source;

8 a signal input port coupled to the optical fiber;

9 a signal output port coupled to the optical fiber;

10 a pump input port coupled to the optical fiber;

11 a first lossy member coupled to the optical fiber and positioned
12 between the first and second lengths of amplifier fiber, the first lossy
13 member being lossy in at least one direction;

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14 a pump shunt coupled to the signal input port and the signal output
15 port;
16 and
17 a receiver coupled to the optical fiber.

1 47. The system of claim 46, wherein the broadband booster
2 amplifier comprises:

3 a plurality of transmitters transmitting a plurality of wavelengths;
4 a combiner coupled to the plurality of transmitters;
5 an optical fiber coupled to the combiner, the optical fiber including
6 a first length of amplifier fiber and a second length of amplifier fiber, the
7 optical fiber configured to be coupled to a signal source and a pump
8 source;

9 a signal input port coupled to the optical fiber;

10 a signal output port coupled to the optical fiber;

11 a pump input port coupled to the optical fiber;

12 a first lossy member coupled to the optical fiber and positioned
13 between the first and second lengths of amplifier fiber, the first lossy
14 member being lossy in at least one direction; and

15 a pump shunt coupled to the signal input port and the signal output
16 port.

1 48. A broadband communication system, comprising:

2 a transmitter;

3 an optical fiber coupled to the transmitter, the optical fiber
4 including a first length of amplifier fiber and a second length of amplifier
5 fiber, the optical fiber configured to be coupled to a signal source and a
6 pump source;

7 a signal input port coupled to the optical fiber;

8 a signal output port coupled to the optical fiber;

- 9 a pump input port coupled to the optical fiber;
- 10 a first lossy member coupled to the optical fiber and positioned
- 11 between the first and second lengths of amplifier fiber, the first lossy
- 12 member being lossy in at least one direction;
- 13 a pump shunt coupled to the signal input port and the signal output
- 14 port;
- 15 a broadband pre-amplifier coupled to the optical fiber; and
- 16 a receiver coupled to the broadband pre-amplifier.

1 49. The system of claim 48, wherein the broadband pre-
2 amplifier comprises:

- 3 an optical fiber including a first length of amplifier fiber and a
- 4 second length of amplifier fiber, the optical fiber configured to be coupled
- 5 to a signal source and a pump source;
- 6 a signal input port coupled to the optical fiber;
- 7 a signal output port coupled to the optical fiber;
- 8 a pump input port coupled to the optical fiber;
- 9 a first lossy member coupled to the optical fiber and positioned
- 10 between the first and second lengths of amplifier fiber, the first lossy
- 11 member being lossy in at least one direction;
- 12 a pump shunt coupled to the signal input port and the signal output
- 13 port;
- 14 a splitter coupled to the signal output port; and
- 15 a plurality of receivers coupled to the splitter.

1 50. A broadband communication system, comprising:
2 a transmitter;
3 a broadband booster amplifier coupled to the transmitter;
4 an optical fiber coupled to the booster broadband amplifier, the
5 optical fiber including a first length of amplifier fiber and a second length

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6 of amplifier fiber, the optical fiber configured to be coupled to a signal
7 source and a pump source;

8 a signal input port coupled to the optical fiber;

9 a signal output port coupled to the optical fiber;

10 a pump input port coupled to the optical fiber;

11 a first lossy member coupled to the optical fiber and positioned
12 between the first and second lengths of amplifier fiber, the first lossy
13 member being lossy in at least one direction;

14 a pump shunt coupled to the signal input port and the signal output
15 port;

16 a broadband pre-amplifier coupled to the optical fiber; and

17 a receiver coupled to the broadband pre-amplifier.

1 51. The system of claim 50, wherein the broadband booster
2 amplifier comprises:

3 a plurality of transmitters transmitting a plurality of wavelengths;

4 a combiner coupled to the plurality of transmitters;

5 an optical fiber coupled to the combiner, the optical fiber including
6 a first length of amplifier fiber and a second length of amplifier fiber, the
7 optical fiber configured to be coupled to a signal source and a pump
8 source;

9 a signal input port coupled to the optical fiber;

10 a signal output port coupled to the optical fiber;

11 a pump input port coupled to the optical fiber;

12 a first lossy member coupled to the optical fiber and positioned
13 between the first and second lengths of amplifier fiber, the first lossy
14 member being lossy in at least one direction; and

15 a pump shunt coupled to the signal input port and the signal output
16 port.

1 52. The system of claim 51, wherein the broadband pre-
2 amplifier comprises:
3 an optical fiber including a first length of amplifier fiber and a
4 second length of amplifier fiber, the optical fiber configured to be coupled
5 to a signal source and a pump source;
6 a signal input port coupled to the optical fiber;
7 a signal output port coupled to the optical fiber;
8 a pump input port coupled to the optical fiber;
9 a first lossy member coupled to the optical fiber and positioned
10 between the first and second lengths of amplifier fiber, the first lossy
11 member being lossy in at least one direction;
12 a pump shunt coupled to the signal input port and the signal output
13 port;
14 a splitter coupled to the signal output port; and
15 a plurality of receivers coupled to the splitter.

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